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AD-A220 176

NAVAL POSTGRADUATE SCHOOL
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THESIS

QUALITATIVE FASTENER STANDARDS:
PROCUREMENT ISSUES

by

David John Beck

December 1989

Thesis Advisor: Paul M. Carrick

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No 0704-0188

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited
2b DECLASSIFICATION/DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S)	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION Naval Postgraduate School; 6b OFFICE SYMBOL (If applicable) Code 54	7a NAME OF MONITORING ORGANIZATION Naval Postgraduate School
6c. ADDRESS (City, State, and ZIP Code) Monterey, California 93943-5000	7b ADDRESS (City, State, and ZIP Code) Monterey, California 93943-5000
8a. NAME OF FUNDING/SPONSORING ORGANIZATION; 8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10 SOURCE OF FUNDING NUMBERS: PROGRAM ELEMENT NO; PROJECT NO; TASK NO; WORK UNIT ACCESSION NO

11 TITLE (Include Security Classification)
QUALITATIVE FASTENER STANDARDS: PROCUREMENT ISSUES

12 PERSONAL AUTHOR(S)
Beck, David J.

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Master's Thesis	FROM ____ TO ____	1989, December	95

16 SUPPLEMENTARY NOTATION The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Counterfeit or Substandard Fasteners; Standards and Standardization; Standards and Specifications; Hardware; Fasteners.

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

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20 DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION Unclassified
22a NAME OF RESPONSIBLE INDIVIDUAL Prof. Paul M. Carrick	22b TELEPHONE (Include Area Code) (408) 646-2939; 22c OFFICE SYMBOL Code 54Ca

DD Form 1473, JUN 86 Previous editions are obsolete SECURITY CLASSIFICATION OF THIS PAGE

S/N 0102-LF-014-6603 UNCLASSIFIED

Approved for public release; distribution is unlimited

Qualitative Fastener Standards: Procurement Issues

by

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
December 1989

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ABSTRACT

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TABLE OF CONTENTS

ACKNOWLEDGMENTS

I would like to thank my wife, Lisa, for her patience, support, editing, and encouragement during the thesis process.

I would like to thank Dr. Paul Carrick, my thesis advisor, for his invaluable guidance.

I. INTRODUCTION TO STANDARDS AND FASTENERS

Fasteners play a crucial role in the world today. Fasteners hold together bridges, buildings, turbines, aircraft, and nearly any multi-assembly item. They are sometimes taken for granted, as most individuals assume fastening has been satisfactorily considered. Further, there are a multitude of fasteners and fastener applications. Fastener standards are the basis for production, procurement and use during the engineering process on complex equipment.

Standards are the cornerstone of the fastener industry, as in any industry. Recently, there has been some compromise in the use of fastener standards. As a result, the industry and the users are at risk.

A. STANDARDS IN AN EXCHANGE ECONOMY

Standards are a quiet force in an exchange economy. Their existence and use are generally not stressed in education. However, standards are becoming increasingly more important in controlling the problems in modern society. They are a critical component in bridging the communication gap between buyers and sellers, whether it is a physical item or a procedure.

Standards perform controlling actions or functions. This can be examined in the most basic sense in terms of codes of behavior. If people do not conform to society's customs, they will invariably be ostracized from the community. This applies in an exchange economy. If businesses do not follow their industry and legal standards they will not be competitive, and will probably not survive.

There are two forms of standards: mandatory and voluntary. Voluntary standards are normally generated by trade associations and other specialized groups, such as the Department of Defense (DoD). These organizations generate standards for their industry or group. They are written to benefit the industry while attempting to satisfy the buyer.

Both voluntary and mandatory standards are generally considered beneficial. They work because society has chosen to comply with and accept them. The success of standards is primarily attributed to the honesty of people, rather than to regulations.

Enforcement of mandatory standards is accomplished by civil remedies or criminal penalties such as fines or imprisonment. Voluntary standards are enforced by the market, with the buyer performing tests to ensure compliance. Some standards include test methods for verifying quality. However, they normally leave it to the buyer to ensure the tests are performed.

B. THE ROLE OF FASTENERS

Fasteners have a far-reaching effect on the world today. The fastener industry is one of the most basic elements in any economy. It supplies over 40 billion bolts, nuts, screws, rivets, and specially engineered products to the automotive industry alone, each year.

Fasteners are critical elements, however, they are a silent segment of the industrial world, similar to standards. Rarely is there discussion of how fasteners successfully perform in common applications. The quality of bolts is generally taken for granted. Traditionally, the quality has been unquestioned. However, there has been a breakdown in the compliance of voluntary standards. This has placed fasteners in an untenable situation in the market place. The quality is no longer assumed or taken for granted.

C. SUMMARY

Fasteners are key elements in the world economy today. However, where the quality of fasteners used to be taken for granted, that is no longer the case. The standards under which fasteners are manufactured have not been universally complied with.

This thesis will examine the counterfeit fastener problem as it relates to the Department of Defense. The related fasteners used by the military will be reviewed, as well as the standards used to procure those fasteners, and the methods by which the standards are applied within the Department of Defense. An example of the selection and procurement process of fasteners by the Navy will be critiqued. This document will explore these questions and provide some possible preventive measures.

II. COUNTERFEIT AND SUBSTANDARD FASTENERS

The term "fastener" is very broad. Fasteners can be anything from lashings that hold wood together, to rivets, nuts, bolts, and nails. Specifically, this thesis examines the externally threaded class 8 and 8.2 bolts, where the greatest problem with substandard and counterfeit fasteners has been found to exist.

A. FASTENER STANDARDS

Fastener standards play several roles. A standard of uniformity makes interchangeability between fastener manufacturers possible. Standards of uniformity widen the markets and increase the sources of supply by allowing easy access to information and easy entry into the fastener industry; which facilitates competition. [Ref. 1:pp. 37-38]

Fastener standards also provide standards of quality. This is exemplified by the use of grading systems. The grade usually indicates uniform products. In the case of fasteners, quality is also addressed. Each grade gives specific measurements for quality and a means of testing those measurements.

Several organizations write fastener standards. The primary fastener standard writing organizations are: the U.S. government, the American Society of Mechanical Engineers (ASME), The American Society for Testing and

Materials (ASTM), the Society of Automotive Engineers (SAE), the Industrial Fasteners Institute (IFI), and the International Organization for Standardization (ISO).

Many of the standards generated by these organizations duplicate or build on the other organizations' standards. An example would be ASTM standard A 354-86. The base document for this standard is SAE standard J429. The ASTM standard then builds on the base, indicating the additional requirements necessary for a fastener to be identified by this standard.

The use and compliance of standards generally benefits the market. However, ensuring compliance of fastener standards has been eliminated for the sellers by the standards writing organizations. The standards, as drafted, indicate that the buyers are responsible to ensure compliance with the standard. For example, ASTM standard A 354 inspection requirements are "If the inspection described in 11.2 is required by the purchaser, it shall be specified in the inquiry and contract or purchase order." The SAE specification J429 calls for the manufacturer to perform tests. There is no requirement in either standard to report substandard test results to the buyer, unless specifically requested.

As standards are currently written, the buyer is responsible for assuring that the fasteners meet the standards. Currently, only the large fastener consumers have the resources to satisfy the testing requirements of the standards described. However, most buyers of fasteners are small businesses. A large company, such as Lockheed, has laboratories internal to the corporation for in-depth testing of fasteners. Small purchasers must contract out for laboratory testing of incoming stock, if they wish to verify the fastener's grade.

B. FASTENER TYPES

Following is a brief explanation of how the grading system for bolts, screws, studs, and U-bolts is organized.

The Society of Automotive Engineers standard J429 covers the mechanical and material requirements for steel bolts, screws, studs, and U-bolts used in automotive and related industries. The bolts are in grades 1, 2, 5, 5.1, 5.2, 7, 8, and 8.2. Appendix A is the table from SAE standard J429. A comparison of 8 and 8.2 bolts will follow, as they were the most commonly counterfeited or substandard fasteners.

Grade 8 fastener products are bolts, screws, and studs. These fasteners must have a proof load of 120,000 pounds per square inch and a tensile strength of 150,000 pounds per square inch. The yield strength minimum must be 130,000 pounds per square inch. This grade of fastener will perform satisfactorily to service temperatures up to 450 degrees fahrenheit. They must have a surface hardness of 58.6 on the Rockwell 30N hardness scale, and a minimum and maximum core hardness of C33 to C39 on the Rockwell C hardness scale. The hardness scales will remain consistent throughout this thesis for comparison purposes. Figure 1 shows the headmarkings of both grades 8 and 8.2.

SAE 8 8.2

Figure 1. Grade Markings

The material composition of grade 8 fasteners is a medium carbon alloy steel. The carbon alloy consists of carbon, manganese, silicon, copper, and a limited amount of chromium. There are other elements that can be used to produce a medium carbon alloy steel. When produced, the grade 8 steel fastener must consist of, at a minimum, 28%, and no more than 55% of the medium carbon alloy. The Society of Automotive Engineers standard J429 allows the buyer and producer to specify the exact medium carbon alloy which will be used. Both grades 8 and 8.2 fasteners are quenched and tempered.

The benefit of a medium carbon alloy steel is a fastener with more load carrying capability per unit cost of any known metal. These fasteners are known as "forgiving" as they can absorb punishment and service abuse. They possess the most attractive balance between cost, manufacturing convenience, and superlative mechanical properties. [Ref. 2:p. 63]

Grade 8.2 products are bolts and screws. These fasteners must have a proof load of 120,000 pounds per square inch and a tensile strength of 150,000 pounds per square inch. The minimum yield strength must be 130,000 pounds per square inch. Grade 8.2 fasteners do not perform as well as the grade 8 fasteners in temperature extremes. They must have a surface hardness of 61 on the Rockwell 30N hardness scale, and a minimum and maximum core hardness of C35 to C42 on the Rockwell C hardness scale. Figure 1 shows the headmarkings for 8.2.

The material composition of grade 8.2 fasteners is a low carbon martensite steel. This is not an alloy steel. The carbon martensite content must fall between 15% and 25% of the total fastener weight. [Ref. 3:pp. 125-130] Boron is also an element of this steel. By adding boron, the grade 8.2 bolt will have the same strength properties as the grade 8 bolt. However, this addition causes fastener performance at elevated temperatures to be inferior, which makes grade 8 bolts generally preferred for the higher strength demands. [Ref. 2:pp. 65-66]

Grade 8.2 has excellent workability and strength properties. This type of fastener can be case hardened and welded. Case hardening hardens the surface of a fastener by a high temperature shallow infusion of carbon followed by quenching. Grade 8.2 has extended life, and improved surface quality. Further, it eliminates the need to anneal or temper the material prior to placing the head on the fastener. Use of this type of material is economically attractive, however, its stress relaxation properties at moderately elevated temperatures is inferior. There is potential to use the low carbon martensite steel in loads where the bolt would be required to fail before the nut or expensive end item. [Ref. 2:pp. 61-63]

Selection between the grades 8 and 8.2 fasteners is determined by application. The grade 8 fastener would more probably be used in an application such as engine parts. The grade 8.2 would be found holding structures together, particularly if welding to the fastener was required. Cost is also a factor. The least expensive fastener material is low carbon steel. As the carbon content increases, alloying elements are also added, which drives up the cost. Therefore, grade 8.2 fasteners are less expensive. For a large consumer of fasteners, such as DoD, using grade 8.2 can be a significant cost savings, if the performance requirements can be satisfied. [Ref. 2:p. 42]

Headmarkings are required for grades 8 and 8.2 fasteners. They must be marked as indicated in Figure 1 and Appendix A. Further, the manufacturer's identification symbol must be marked on the top of the head. This provides a means for identifying the manufacturer after the fastener has been purchased. The American Society for Testing and Materials standards have similar requirements for their high grade steel fasteners.

The SAE standard J429 calls out five general fastener tests or methods. Those tests are: hardness, surface hardness, proof load, axial tensile strength, and wedge tensile strength. Grades 8 and 8.2 fasteners require some, or all the tests, depending on the length of the fastener. Hardness is the only test required regardless of the fastener length.

The hardness test is a measure of a material's ability to resist abrasion and indentation. This test is tremendously important as a specification. It is quick, easy to perform, and nondestructive. There is also a close correlation between the hardness and the tensile strength of steel fasteners. It is performed at mid-radius in the threaded portion of the fastener. The hardness reported is the average of four readings located 90 degrees from one another. The minimum value corresponds to the minimum tensile strength. The maximum value represents a level of hardness beyond which the fastener would be unacceptably brittle.

Surface hardness testing, as the name indicates, is the hardness of the fastener's surface. This test is performed on the ends or unthreaded shanks of the fasteners. It has similar benefits to the hardness test, with slightly less reliable results. The surface hardness is not always uniform across the entire surface of a fastener. This is a limitation of the manufacturing process. As a result, the surface hardness test can indicate artificially high hardness, depending on the location of the test. When this occurs, additional testing is required prior to failing a fastener for excessive hardness.

A proof load test consists of stressing the fastener with a specified load without permanent deformation. The proof load is an absolute evaluation. The length of the fastener is measured prior to the test and then remeasured after the load has been removed. There should be no differences in the length of the fastener, less allowances for measurement error.

There are two types of tensile strength tests, axial and wedge. The tensile test measures the maximum tension applied load which a fastener can support before or coincident with its failure. The axial test measures a direct load on the fastener. The wedge test places a beveled wedge under the head of the fastener. When the test is being performed, the wedge induces a severe bending stress at the joint of the head of the fastener and the shank. The fastener must support the load and the stress to be acceptable.

C. BACKGROUND

The counterfeit and substandard fastener issue deals with the introduction of falsely marked and nonconforming fasteners into inventories of the Department of Defense and the civilian sector. This question has drawn much media attention. The impact can be far-reaching, and the facts of the issue can be clouded by the sensationalism of the in-use failures of counterfeit and substandard fasteners.

The counterfeit and substandard fastener problem was initially discovered in January 1985 by Grant Fasteners Incorporated, of Houston, Texas. The company found fasteners of unknown origin and content in their inventory. Mr. Tommy Grant, the owner of Grant Fasteners, did not know if the fasteners were nonconforming or counterfeit. As the actual source was unknown, so were the engineering capabilities of the fasteners.

The exact point in time when the bad fasteners started entering the country is unknown. It is estimated to have begun in 1974. Mr. Sims, a special assistant to the House of Representatives Subcommittee on Oversight and Investigations, stated, "The evidence that we have is that Americans actually went over there [Japan] in the beginning and had the bolts made with the wrong markings on them." Initially, the organizations sponsoring counterfeiting appeared to be distributors trying to obtain a competitive market advantage. When it was determined that this was not difficult, Japanese, Korean, and Taiwanese firms followed suit. [Ref. 4:p. 58]

The Industrial Fasteners Institute (IFI), which is a fastener manufacture's trade organization, learned of Mr. Grant's observations and they submitted eight samples from Grant Fasteners' inventory for testing. The samples were submitted 12 June 1985, and were all marked as grade 8 fasteners, according to SAE standard J429. Four of the eight fasteners were improperly marked and those that were marked were not recognized as a North American manufacturer. None of the eight fasteners were made of the correct combination of materials called for by the SAE standard.

Based upon the test results, the IFI initiated a program to test samples from geographic areas adjacent to waterfronts in the United States. Over 300 samples were obtained and tested. The conclusion was 70% of the samples submitted were out of specification tolerances. The IFI notified their member companies in April 1986 and issued a news release to the general public on 2 May 1986.

The Defense Industrial Supply Center (DISC) became aware of the fastener problem when the IFI issued their press release in May 1986. On 2 July 1986, DISC issued an alert on the Government Industry Data Exchange Program (GIDEP), warning of the problem. They also started their own investigation at about the same time. By October, DISC had completed testing of 321 samples, which confirmed IFI's concerns. The Defense Logistics Agency (DLA), of which DISC is a subordinate command, issued a news release on 12 December 1986, reporting their findings.

A follow-on investigation was started by DISC to inspect their inventory, to support criminal investigations, and to develop strategies to prevent recurrence. The investigations led to DISC freezing their grade 8 inventories in June 1987. By 15 July 1987, DISC determined that approximately 29% of its grade 8 inventory failed because of improper material composition. DISC ultimately expects to find a failure rate at around 25% in their existing inventories; the failure rate reduction resulting from more precise statistical procedures. [Ref. 4:p. 190]

In December 1988, DISC declared their inventories clear of nonconforming fasteners and that testing of new incoming orders indicated 100% conforming stock. Their corrective actions to prevent recurrences were:

- Tighten up procurement policies.
- Institute contract clauses calling for better traceability of fasteners.
- Institute contract clauses addressing test measurement equipment.
- Sample and test each grade 8 contract.

The civilian fastener market has been grappling with the problem since it was discovered. The IFI has published an advisory for correcting the situation. Their recommended actions include:

- Making manufacturers' headmarks mandatory.

- Qualifying all fastener vendors.

- Continuing U.S. Customs Service investigations of all bolts.

- Examining and purging fastener stocks.

- Reviewing all past purchases. [Ref. 5:pp. 9-10]

The IFI believes that the root causes of the fastener problem are greedy and unscrupulous distributors who import the material. They also suspect that some federal acquisition regulations compound the problem; particularly the $25,000 window which allows federal agencies to make purchases below that amount without prior qualification of the vendor. [Ref. 5:p. 8]

The greed has been allowed to exist because of the market organization. With all standards being voluntary, there is an incentive to take advantage of the market condition by counterfeiting. Current standards do not have any means for enforcement, which simplifies counterfeiting.

The actual volume of fasteners used is large. It is estimated that over seven billion bolts and large screws are used in the United States each year. Of those, approximately 20% are of the high strength grade 8 class. The grade 8 bolt is used in over 500 different weapons systems. Annually, over $3.4 billion are consumed on fasteners. The C-5A aircraft uses 2.2 million fasteners on each airframe. At a more personal level, the number of fasteners used on dishwashers manufactured each year is about 270.8 million.

Ranges use 369.3 million fasteners, and clothes dryers use 688 million fasteners. These examples represent all types of fasteners, not just grades 8 and 8.2. It is obvious that the nation could not operate without fasteners. [Ref. 6:pp. 56-67]

D. SUMMARY

This chapter has provided an overview of the fastener problem and how it developed. To show the magnitude of the situation, a review of fastener consumption and use has been presented.

A general description of grades 8 and 8.2 fasteners was supplied, with direct reference to the SAE standard J429, which is the basis from which grades 8 and 8.2 are derived. Key elements in the testing, marking, and use of the fasteners were considered.

A description of fastener standard setting organizations was presented. There was an examination of the role of standards in the fastener industry. Additionally, compliance with voluntary fasteners was reviewed. The majority of standard compliance responsibilities is placed upon the consumer.

III. STANDARDS AND SPECIFICATIONS

Standards and specifications are critical components in any economic exchange. They are the elements in the contracting process that serve as a basis for defining what the buyer and seller exchange. Accurate and usable standards and specifications have a significant effect on the successful procurement or sale of any material or service. This fact is equally applicable in both the civilian and military economies.

A. BACKGROUND

The need for standards and uniformity has long been recognized. Weights and measures to control dealings between individuals are the earliest known written standards. These were developed 5000 years ago by the Egyptians. The standard system was called the Egyptian Royal Cubit. This system was widely used for a time. However, as civilizations succeeded each other, the system failed. [Ref. 7:pp. 5-6]

As the world shrunk with improved transportation and communications systems, the problems associated with a lack of standards have been highlighted by hardship. For example, at the outbreak of World War II there was no unified screw-thread standard between the Allies. Early in the war, supply depots had identical parts, with the exception of fasteners. There was an emergency compromise, but after the war the problem remained.

The Department of Defense (DoD) determined that standardization and specifications could improve operational readiness and cost effectiveness. DoD's Defense Standardization and Specification Program (DSSP) was established in 1952. It was intended to be a single, integrated defense-wide program with a uniform series of specifications, standards, and related documents. DSSP is under the cognizance of the Under Secretary of Defense for Research and Engineering. Further, there remains a statutory requirement for this program. [Ref. 8:p. 9]

The DSSP primarily applies to common use systems, subsystems, equipment, components, parts, materials, engineering practices, and technical data. The objective is to ensure material standardization throughout the design, development, and acquisition processes. There are two general procedures which DSSP is tasked with:

> (a) a planned program under which specifications, standards, handbooks, engineering drawings and other standardization documents are prepared and maintained to meet essential requirements with optimum efficiency; and (b) a decentralized program with management authority and responsibilities of portions of the program delegated to the DoD components. [Ref. 9:p. c-13]

The DoD Index of Specifications and Standards lists more than 45,000 standardization documents produced by the Federal Government or industry groups. The result is reduced duplicative development and testing costs, and control of the proliferation of items in DoD inventories.

Mr. F.A. Sweet, formerly with the Canadian Standards Association, believes there are four basic values of standards: they educate, they simplify, they conserve, and they are a base upon which to certify. Standards educate in the sense that they set forth ideals or quality goals. They enable manufacturers and consumers to be more knowledgeable about the exchanges they are making. Standards simplify by reducing the number of sizes, the variety of processes, and the amount of inventory. Without standards, these items would tend to increase the overhead costs of doing business, which the consumers must pay. Conservation is obtained by more precise controls, careful design, and more efficient large scale production. Finally, standards become the basis for determining quality. This can be critically important in a free market economy. [Ref. 7:p. X]

In a broad sense, a standard is a "category of documents whose function is to control some aspect of human endeavor." [Ref. 7:p. 2]

There are two general standard types. They are standards for uniformity and standards of quality. Standards for uniformity are concerned with a product being consistent or the same. For instance, thread types on fasteners must be consistent between manufacturers for wide commercial acceptance. Quality standards consider better or worse. Traditionally, these standards are specified in minimum values. "Better" means the item meets the standard, "worse" means it does not. Quality standards are more likely to require enforcement. [Ref. 1:pp. 8-9]

In the micro, business sense, standardization and standards have specific meanings. These definitions apply in both the civilian and military sectors.

Standardization is defined as: "a management function for the coordination of individual decisions with the objective of optimizing diversity." [Ref. 10:p. 4] In simpler terms the statement implies: be consistent in what items are utilized unless there is a strong overriding reason not to remain standardized.

Standards are defined as: "documents that establish engineering and technical requirements for processes, procedures, practices and methods that have been adopted as [routine] standard." Their function is to control variety. Specifications: "establish requirements in terms of complete design details or in terms of performance, but in most cases in terms of both design and performance." [Ref. 11:pp. 10-11]

B. VOLUNTARY STANDARDS

Differing from most foreign countries, the United States allows private organizations to do most of the creation of standards. There are approximately 400 private groups that perform these functions. As an illustration, in 1964 less than 3% of the 14,000 standards existing were written by the government. [Ref. 1:p. 81]

The United States has no formal standards policy. The National Standards Policy Committee (NSPAC) recommended development of a national policy in 1977. It was suggested that the American National Standards Institute (ANSI) fill this role. A document to this effect was released for public comment. However, some organizations could not see ANSI filling this role without changing its structure. ANSI has responded to the recommended changes and their plan was released for public review in January 1981. Because of the factors involved, the restructuring plan has not yet been fully implemented. [Ref. 7:pp. 14-15]

ANSI is an unusual standards organization. They do not create standards, but rather they act as the national coordinating organization for standards. ANSI encourages development and approves standards which are supported by a national consensus.

According to Charles D. Sullivan, ANSI's purposes are:

> (1) Serve as the national coordinating institute for voluntary standardization and certification activities of the United States; (2) to further the voluntary standards movement as a means of advancing the national economy; (3) to insure that the interests of the public have appropriate protection and participation; (4) to provide the means of determining standards and certification programs; (5) to establish, promulgate, and administer procedures and criteria for recognition and approval of standards as American national standards; (6) to establish procedures for recognition and accreditation of certification programs; (7) to cooperate with government standards and voluntary standards of industry; (8) to promote knowledge and use of American national standards and accreditations;

(9) to represent the interests of the United States in international, non-treaty standardization and accreditation programs; (10) to serve as a clearing house for information on standards and certification in the United States and abroad. [Ref. 7:pp. 29-30]

There are many voluntary standards setting organizations in the United States. They are composed primarily of industry trade associations or various specialized engineering societies. Examples include: The American Society of Mechanical Engineers (ASME), The Institute of Electrical Electronics Engineers (IEEE), The American Society for Testing and Materials (ASTM), and The National Fire Protection Association (NFPA).

These societies consist of members from the industries they represent. The people who write the standards are theoretically independent of their full time employers. They help develop standards while, often, on company time. Therefore, the companies using the new standards are well represented during standards creation. Consequently, standards are not always as objective nor do they serve the general good of an industry as they might otherwise be. It is possible that a standard would be written in a specific manner simply because a dominant corporation desires it.

When large corporations have such a dominant role in setting standards, it follows that new standards are written in their best interest. Although not necessarily incorrect, this aids in the dominant companies remaining dominant. It also makes market entry difficult for new firms. In effect, these types of standard setting procedures may not always work in the public's best interest. [Ref. 1:pp. 89-90]

The use of voluntary standards is generally open to all. Organizations like ASTM encourage the use of their standards. In fact, without widespread use of the voluntary standards already generated, conducting business would be severely hampered. To demonstrate how significant standards are, Figure 2 shows the use of standards in typical aerospace applications.

C. GOVERNMENT STANDARDS

The standards and specifications used by the Department of Defense (DoD) are divided into three groups: federal, military, and nongovernment. Federal specifications cover a large portion of civilian type products and services used by DoD. Military standards and specifications pertain to products and services that are inherently military. There are over 45,000 military standards documents. The nongovernment standards are voluntary standards issued by organizations like the Society of Automotive Engineers (SAE) and ASTM. These standards are available to the general public. The order of preference for DoD is nongovernment, federal specification, and military specification. [Ref. 8:p. 12]

There are three basic federal standards documents: Commercial Item Descriptions (CIDs), Federal specifications, and Federal standdards. CIDs are federal specifications

USE OF STANDARDS IN TYPICAL AEROSPACE PRODUCTS

		Number of Different Specifications & Standards*	%	Estimated Total Number of Applications	%
Tactical Fighter 	DoD	1,100	55	48,000	32
	NAS	200	10	38,000	26
	SAE	80	2.5	100	
	ASTM	10	0.5	15	
	**Non Standards	600	30	62,000	42
		1,990		148,115	
Wide Body Airliner 	DoD	419	20	10,000	6.4
	NAS	122	6	50,000	32
	SAE	86	4	320	2
	ASTM	120	6	1,000	0.6
	Miscellaneous Stds	376	18	9,500	6
	**Non Standards	956	46	85,000	53
		2,079		155,820	
Maritime Patrol Plane 	DoD	713	34.5	35,000	28
	NAS	192	9	20,000	16
	SAE	55	2.5	400	0.3
	ASTM	90	4	900	0.7
	Miscellaneous Stds	285	13.5	1,600	1.3
	**Non Standards	767	36.5	66,000	53.7
		2,102		123,900	
Commercial Jet Engine 	DoD	107	17	8,061	34
	SAE	32	5	1,224	5
	ASTM	2		2	
	Miscellaneous Stds	297	48	5,156	21
	***Non Standards	186	30	9,750	40
		624		24,193	

* Airframe only — does not include engines, avionics, or ground support equipment.
** Includes parts, materials and processes for which standards have not been prepared by a recognized standardization organization as well as items uniquely designed for that aircraft.
*** As above except does not include items uniquely designed for the engine.

Source: [Ref. 10:p. 10]

Figure 2. Use of Standards in Typical Aerospace Products

which describe the key physical or functional characteristics of acceptable commercial products. This type of specification is used when there are a minimum of special requirements. Federal specifications contain a complete description of the required items or materials. They are used when a CID cannot adequately describe what is required and the specification will be used by two or more federal agencies. A federal specification might be used to purchase a two-way radio with an unusual frequency range. The final type is a federal standard. Federal standards cover engineering or management processes, practices, or techniques having multiple agency interest.

Military standards documents are in two groups: military specifications and military standards. Military specifications, like federal specifications, are a description of a product, service, process, or procedure. They also usually are a significantly modified commercial product which satisfies military requirements. Military standards are like federal standards, and as before, they must be intrinsically military. These standards are identified as MIL-STDs or DoD-STDs (for metric standards).

Nongovernment standards are drafted in accordance with the association's or society's policies. These are commonly called voluntary standards. The government uses these standards in three ways: adoption, reference, or excerpts. [Ref. 8:pp. 12-14]

Government standards are generally open to all. As indicated in Figure 2, the standards are widely used outside the military and federal government.

D. STANDARDS BENEFITS AND DRAWBACKS

The single greatest benefit of standards is the service they provide in an open economy. Without standards the modern industrial world would not have progressed nearly as fast. Standards allow uniformity, which provides for interchangeability. When advances in technology have occurred, they have been standardized. This standardization has aided in other organizations building on what has been previously developed and capitalizing on economies of scale. The whole process has expedited growth in open economies. The necessity of standards is reflected by the fact that many voluntary standards become laws.

The Department of Defense has four specific purposes or identified benefits of standardization. They are:

- To reduce unnecessary and inefficient proliferation of generally similar items.
- To reduce risks associated with developing and producing new products and services.
- To use standardization as a stepping stone for evolutionary improvements.
- To conserve resources by minimizing training, technical data, engineering and support requirements. [Ref. 8:p. 3]

One benefit is improved knowledge for the buyer. Traditionally, buyers have less information than the sellers. Sellers, when they are the manufacturers, have intimate knowledge of the product. Occasionally, they even set the industry standard for a particular product. The only time the buyer can counter this situation is when they are large or well organized. General Motors was able to act as the large buyer. They successfully influenced the production of gas types because they produced the machines that consumed the fuel. Standards are a factor in leveling out the knowledge imbalance.

The use of standardization in Federal Supply Class 5962 realized nearly $1 billion in cost avoidances. This supply class covers microcircuit devices. The results cited here were achieved through the standardization effort on one standard; MIL-M-38510/101. [Ref. 10:pp. 69-70]

There are basically two drawbacks to standardization: withholding of desired variety from the market and facilitation of illegal activity. The withholding of desired variety would include over-standardization and the problems associated with quality levels being set at undesirable points via standards.

Although less common than illegal activity from standards, withholding of wanted variety does occur. The seller usually supports standards that will limit the use of lower profit items from the market. For example, the airlines resisted the introduction of coach seats. More recently, U.S. automobile manufacturers resisted the small car. [Ref. 1:p. 31]

Standards of uniformity may induce oligopolistic collusion. With developed standards, it is much easier to fix prices. They can also be used to handicap or exclude competitors from the market. If the specification or standard is written in a certain form, it can eliminate certain competition. An example: the APS plastic pipe manufacturers fought back when local building codes prohibited the use of non-steel pipes. [Ref. 1:p. 77] An oligopolistic market may not always be considered a drawback. In markets that require large capital investments, an oligopolistic environment is the only system that would prevail.

For the Department of Defense, the greatest drawback to voluntary standards is that most of them address test methods, processes, recommended practices, and safety. Of the 35,000 nongovernmental standards, 8000 are product standards. As DoD will not use the process type standard, this eliminates over 75% of the voluntary standards available. [Ref. 12:p. 9]

Standard setting organizations are producing additional standards that can increase the confusion level. For example, there are six different standards for approximately the same load bearing requirements as the grade 8 bolt. This also increases the cost of using the standards. Which organization's standard to use and which standard will be acceptable in both cost and application may be the real questions for the standards user. [Ref. 13:p. 8]

E. GOVERNMENT SELECTION OF STANDARDS

The Department of Defense supports standardization and views it as a method to efficiently use resources. There are specific directives on the use of standards. The defense standardization and specification program directive, DoD Directive 4120.3, specifically states "Documents issued by nongovernmental standards producing organizations shall be adopted and used instead of military documents."

The priorities follow: voluntary standards, federal standards and military standards. There has been a policy shift within DoD to increase the use of voluntary standards. The goal, eventually, will be to develop voluntary standards with the private sector and reduce the use of MILSTDs. Other branches of the government are working with the Department of Defense in accomplishing this goal. [Ref. 12:p. 36]

F. GOVERNMENT INTERVENTION IN VOLUNTARY STANDARD SETTING

The government intervenes in standard setting when it believes that private industry, or the public generally, will not act in their own best interest. An example of this might be the Occupational Safety and Health Act, which set standards for worker safety and healthful conditions on the job. This act created the Occupational Safety and Health Administration (OSHA). Prior to OSHA, numerous industries such as textiles, steel mills, and coal mines had a high degree of safety and health-related risks on the job. However, the employers were considered free of any responsibility for job-related injuries. Congress felt that private industry would not act in their employees' best interest without it being forced upon them. Additionally, passing the law implied that the workers were powerless to cause safety standards to be implemented. OSHA was intended to protect every working person from hazardous working environments. Employers now must comply with OSHA's safety and health regulations.

There were two bills before the House of Representatives concerning standards and fastener quality issues. The bills were HR 5051, The Fastener Quality Assurance Act of 1988, and HR 5120, The Standardization of Measurement Act of 1988. However, the two bills were combined into HR 3000. HR 3000 was still pending when this thesis was being prepared.

1. <u>The Fastener Quality Assurance Act, HR 5051</u>

This Act's purpose is "To require that certain fasteners sold in commerce conform to the specifications to which they are represented to be manufactured and to provide for the approval of accreditation systems for laboratories testing fasteners sold in commerce." [Ref. 9:p. 1]

A House Investigating Committee investigated counterfeiting problems in the fastener industry. The volume of fasteners sold was in the billions. Millions of those fasteners were mismarked, substandard, counterfeit, or nonconforming. The Committee determined the military and civilian sectors were being endangered and subject to extraordinary expenses as a result of the substandard fasteners. Further, most of the nonconforming fasteners were produced abroad; which is not surprising as 80% of the fasteners used in the United States are produced abroad. House Resolution 5051 was submitted to correct this problem.

The methods used to correct the problem are in three categories:

- Testing and certification of fasteners.
- Manufacturers' insignias.
- Remedies.

There are a set of requirements for fasteners prior to their being offered for sale, under the testing and certification aspects of the bill. These requirements include laboratory accreditation, laboratory certification of each lot, distributors' responsibilities, and fasteners of foreign origin.

The manufacturers' insignias section requires that all high strength fasteners bear an insignia prior to sale or interstate commerce. The Secretary of Commerce will be required to catalog the insignias.

Remedies are classified as civil remedies and criminal penalties. The civil penalties provide for injunctive relief against any person who falsely represents his products. The criminal penalties effect a means for punishing those persons who knowingly misrepresent their products. Under this bill, they can be fined and/or imprisoned for up to ten years. [Ref. 14:pp. 1-12]

HR 5051 has support from the Industrial Fasteners Institute. They view the bill as a means to correct what they deem as an attack on the engineering standards of North

America. They are urging their members to write Congress in support of this bill. [Ref. 15:p. 8] There is broad support from individual companies. They have expressed their support for the bill both in Congressional testimony and through their industry publications. The American Association for Laboratory Accreditation supports HR 5051 as a more responsive and less expensive solution to the fastener problems, vice HR 5120. [Ref. 16:pp. 91-92]

There is not unanimous support for HR 5051. The National Aeronautics and Space Administration (NASA) thought the bill was well-written and well-intended. However, they believe the bill will "merely impose additional, burdensome, and possibly ineffective regulatory requirements...." [Ref. 16:p. 78] There are several small businesses that believe HR 5051 will create excessive paperwork requirements. The Subcommittee on Science, Research and Technology hearings record contains several letters to that effect. They were submitted by a number of small fastener distributors, such as the Dell Fastener Corporation, and Uneeda Bolt & Screw Company. [Ref. 16:pp. 100-105]

2. The Standardization of Measurement Act, HR 5120

The purpose of this act is "To provide for a system of standardization of measurement of bolts to increase bolt quality and reduce the danger of substandard bolt failure, and for other purposes." [Ref. 17:p. 1]

The Congressional Investigating Subcommittee found that "Counterfeit and substandard bolts and other metal fasteners pervade the United States economy, and their use has dramatically increased the risk of equipment and infrastructure failures...." [Ref. 17:pp. 1-2] Problems with standards of measurement and testing were also identified. HR 5120 is a proposed solution to those problems.

To accomplish the purposes of the bill and correct the identified problems, the National Bureau of Standards (NBS) is tasked with several activities. They must:

- Develop recommendations for improving standardization of bolt measurement.
- Coordinate with voluntary standardization organizations the methods in which to implement the recommendations.
- Accredit laboratories for performing the testing required by the recommendations.

If HR 5120 had been passed and signed, effective 1 January 1991, bolts would have been certified under this bill before they could be defined as high strength steel bolts.

A review of current literature indicates no support for HR 5120. Congressional records and testimony have repeatedly favored HR 5051 over HR 5120, or have been completely against HR 5120. The organizations that do not support this bill include: NASA, NBS, Industrial Fasteners Institute, and the Aerospace Industries Association, to name a few. The general opinion appears that this is not the most effective method to solve the fastener problem. [Ref. 16:pp. 82-106]

3. <u>The Fastener Quality Act, HR 3000</u>

This Act is a compromise of HR 5120 and 5051. For whatever political reasons, the two bills were combined. Some provisions that were unacceptable in HR 5120 have been deleted or revised in this bill.

The purpose of the bill is to:

> ...require that certain fasteners sold in commerce conform to the specifications to which they are represented to be manufactured, to provide for accreditation of laboratories engaged in fastener testing, to require inspection, testing, and certification, in accordance with standardized methods, of fasteners used in critical applications to increase fastener quality and reduce the danger of fastener failure,.... [Ref. 18:p. 2]

To accomplish this, several procedures will be required by law. All fasteners will be required to conform to the standard represented by the manufacturer and be tested, inspected, and certified to that effect. The testing, inspecting and certifying will have to be accomplished by a certified lab. A laboratory certification program will be established in the Department of Commerce.

There is a small lot exception for the testing, inspecting, and certifying requirements. This allows lots of less than 50 fasteners to be sold without the requirement for testing. The intent is to relieve the small businesses of the burden and cost of complying with the law.

The sale of fasteners subsequent to manufacture will also have requirements under this bill. All fasteners sold will have a certification from the original manufacturer. This also applies to fasteners of foreign origin. It will be against the law to comingle lots of fasteners with one another. All fasteners will be required to have head markings identifying the manufacturer.

There are both civil and criminal penalties under this bill. Under the civil paragraph, injunctive relief can be provided. The criminal penalties allow for up to five years in jail.

As this bill was just recently drafted, there has not been any recorded feedback regarding support. However, the National Fastener Distributors Association worked with the committees drafting this bill and it is assumed they support the current document.

G. SUMMARY

In this chapter, an overview of standards and specifications has been presented. It included the sources of standards, how they are set and how they are used. The benefits and drawbacks were considered. The government's policy in selecting standards was discussed and finally the government's attempt at intervention in the standards setting process was reviewed.

Standards are a key element in the procurement process. Though not without flaws, they have served the purposes intended. Future development in standardization, with items such as living specifications and automated standard retrieval, will undoubtedly improve the process.

IV. DEFENSE INDUSTRIAL SUPPLY CENTER

The Defense Industrial Supply Center (DISC) is an excellent example for examining how a buyer defines and assures fastener grades. They are the largest government organization in terms of numbers of fasteners purchased. The introduction of counterfeit fasteners at DISC appears to have evolved from an assortment of factors. The counterfeit fastener problem, however, is nationwide and not exclusively within DISC. What they have experienced and learned, however, is important to all Department of Defense (DoD) activities that procure fasteners.

A. HISTORY

The counterfeit fastener problem first came to light in January 1985 when Mr. Grant, of Grant Fasteners, became aware that fasteners in his inventory were of questionable origin. He had suspected a problem for several years prior to 1985. However, the fasteners which could prove his suspicions did not surface until that time. The Industrial Fasteners Institute (IFI), which is a fastener manufacturers trade organization, was informed of the growing counterfeit fastener problem in the commercial market by late 1985, when Mr. Grant's suspicions were reported to them.

The IFI conducted an investigation and published the results in May 1986, with copies to the Congress and several federal agencies, including the Defense Logistics Agency (DLA), of which DISC is a subordinate command. DISC, and many private firms, were receiving bad fasteners during this period and probably had been for several years. [Ref. 16:p. 32]

In response to the IFI information, DISC began their own investigation resulting in a Congressional investigation and a freeze of DISC's grade 8 fastener inventory in June 1987. Subsequently, they tested over 12,000 specimens and evaluated 1200 contracts. There was a 30% test failure rate of DISC inventories. They sent out notices to their customers warning of the problem. [Refs. 16:pp. 48, 58]

DISC took positive corrective action. However, the action was initiated over a year after they became aware of the problem. They changed their procurement policies to include new clauses covering better traceability to the manufacturer, requirements for the manufacturer's logo on each bolt head, and which type of test measurement equipment was called for when verifying fastener quality.

DISC now inspects each contract. Additionally, they have taken some remedial actions against suppliers who knowingly delivered counterfeit fasteners. Those actions have included debarments and legal proceedings. [Ref. 16:p. 70] More specifically, DLA established procedures for reimbursement, repair, or replacement of fasteners that did not conform to contract specifications. There were 15 investigations for criminal action in August 1987, but no indictments have been issued in those cases. [Ref. 4:pp. 233-234]

Today DISC believes their inventories have been purged of counterfeit fasteners. Their new procurement policies appear to have virtually eliminated bad products entering the DoD supply system via DISC. Their acceptance rate is nearly 100%. Suppliers are ostensibly no longer attempting to deceive the government because the institution of the acceptance test requirements assures that deviations will be detected. [Ref. 4:pp. 197-198]

B. CONTRIBUTING FACTORS

Many of the basic procurement policies, regulations, and laws contributed to DISC's fastener problem. Their internal procedures aggravated a bad situation. Between DISC's own procurement practices and federal regulations the stage was set for the counterfeiting of fasteners.

1. Internal Factors

DISC's procurement practices were inconsistent. Contracts were let for fasteners based on MILSTDs, most of which are based on voluntary civilian standards. The civilian standards place the responsibility for assuring the contracted quality on the buyer. In the case of grades 8 and 8.2 fasteners, DISC procured these under SAE standard J429 which specifically places the responsibility on the consumer for assurance of quality contracted. [Ref. 4:p.

189] DISC, however, relied on paper certificates of compliance to assure the required grade. This was the least cost means of ensuring that the required products were received, but it proved ineffective. The Chief of the Test and Evaluation Division of DISC, Mr. James Nicolo, concedes that the counterfeit fastener problem in general was allowed to occur because of "a situation of inadequate enforcement of standard requirements." [Ref. 16:p. 48]

Once the counterfeit fasteners entered DISC's inventories, it was virtually impossible to trace back to the manufacturer or supplier. Suppliers were not required to have head markings on the bolts. Some of the distributors provided fasteners with head markings, but the government had an incomplete record of which markings applied to which fastener manufacturer. The result was that the government received little value by having the head markings.

On those occasions when DISC could track down the supplier, they were usually small businesses who only distributed fasteners, rather than manufacturing them. They would respond by indicating that the fasteners were purchased in good faith from distributors or by going out of business altogether. For these reasons, after-the-fact enforcement was ineffective and did not prevent counterfeit fasteners from entering into the supply system.

DISC was aware of the counterfeit fastener problem for approximately 13 months before they froze their inventories. When questioned about why DISC did not act sooner, General Pigaty, the Commander of DISC, stated, "I don't think we had a real appreciation for how big the problem was." He also believed that DISC was aggressive in pursuing the counterfeit issue, however, they were "Somewhat uncoordinated." [Ref. 4:pp. 198-199]

2. External Factors

DISC certainly knew their system did not respond correctly in assuring quality and contract compliance. However, there were other factors working against their organization which contributed to the fastener controversy.

The Federal Acquisition Regulations (FAR) require all government activities to solicit competitive bids for fasteners and that they be manufactured in the United States. They were required to buy from the bidder with the lowest price. What this competition created was many small distributors buying counterfeit fasteners from overseas manufacturers and passing them off as U.S. manufactured bolts to DISC. Some of the small distributors may have purchased the fasteners from other distributors in good faith, not knowing that they were counterfeit. By purchasing the cheap foreign-made fasteners, they could undercut the U.S. manufacturers' prices.

The Defense Industrial Supply Center was also required, under the FARs, to set aside at least 50% of their fastener business for small businesses. This resulted in most fastener orders having low contract costs and being in small quantities and lot sizes. At one point, there were more than 1800 open contracts at DISC for grade 8 bolts alone.

Many of DISC's attempts to keep counterfeit fasteners out were aggravated by the Small Business Administration (SBA). By law and under the FARs, the SBA determines if a small business is capable of fulfilling a contract. They accomplish this by inspecting small businesses and if found acceptable, issuing a Certificate of Competency (COC). Once a COC is issued they are eligible to bid on appropriate contracts, and if they are the low bidder, must be awarded the contract. However, if DISC has a problem with a supplier and cannot convince the SBA to remove a business' COC, they have no choice but to continue patronizing that contractor. There are several examples of DISC's inability to exclude a company when dissatisfied with nonconforming bolts. One example would be the case of Highland Bolt and Nut of Utica, Michigan. Highland had been supplying DISC nonconforming bolts between 1982 and 1986. DISC tried to deny them contracts. However, the SBA issued a COC which required that Highland, as the qualified low bidder, receive the contracts. DISC repeatedly, but unsuccessfully, tried to convince the SBA to remove Highland's COC. Finally, in 1988, DISC was able to have Highland debarred. [Ref. 19:p. 25]

While DISC was sampling all lots received, they were able to identify 50 vendors who supplied nonconforming fasteners. They took the administrative actions allowed them under the FARs. However, that has not prevented some of the undesirable vendors from continuing to do business with DISC. [Ref. 19:pp. 22-23]

C. CORRECTIVE ACTION

The Defense Industrial Supply Center concedes that they cannot continue to inspect every fastener shipment they receive. They do not have the resources to continue that type of testing. In the future, testing and quality assurance clauses will be written into contracts exceeding $25,000. Contracts below that threshold will be randomly inspected. The quality assurance personnel at DISC will also look at past performance and any other indicators that might make a supplier's quality questionable. The random tests combined with the possible repercussion of no longer being able to do business with DoD is intended to keep the distributors honest. [Ref. 4:pp. 200-202]

The Defense Industrial Supply Centers's situation is unique in that the volume of fasteners handled is large. They indicated that there are inadequate resources available to continue inspecting all lots. This problem must be doubly present for the small business purchasing fasteners. Their volume would not permit them the opportunity of requiring tests from their suppliers. Further, they would not have the resources for a test and evaluation division.

D. FASTENER VOLUME

It is difficult to appreciate the full magnitude of the problem at DISC without understanding the sheer volume of the business they handle. As a command, they supply over 2.5 million items to the armed services. This represents 60% of the total supplies used by DoD. In one year, DISC makes contract payments exceeding $50 billion. They support a wide range of military hardware to all services.

DISC processes an incredible number of fasteners. They manage over 900 National Stock Numbers (NSN) for grades 8 and 8.2 fasteners. They purchased about 100 million grade 8 bolts in a two-year period. DISC has already determined that 30 million of its current fastener inventory is counterfeit. If all fasteners are considered, and not only the grades 8 and 8.2 bolts, the magnitude of the volume increases more than ten-fold.

E. SUMMARY

In this chapter, a history of the fastener problems at the Defense Industrial Supply Center was presented. It included the fact that a civilian distributor discovered the counterfeit fastener problem and how the industry trade organization made the information available for the fastener consumers, including DISC.

DISC's internal procedures allowing the counterfeit fastener problem to enter DoD's supply system were reviewed. The external factors of DISC's problem as a command may have contributed to the problem nationwide, because the contracting procedures encouraged the lowest price. The lowest price motive encouraged small businesses to find ways to undercut the competition, even at the expense of quality.

DISC has now implemented actions to correct the counterfeit fastener problem within their organization. Primarily, they are tightening steps taken to ensure compliance with the standards. It is now believed that DISC's inventories are purged of the nonconforming fasteners.

V. THE F/A-18: A FASTENER SUCCESS STORY

The F/A-18 Hornet is a lightweight and highly maneuverable fighter attack aircraft. This aircraft quickly transforms from the fighter role to the attack role, with only changes in computer software and weapons racks. High reliability and maintainability were designed into the airframe. Maintenance manhours per flight hour were estimated at 10.3 for the F/A-18 where the F-4S, an aircraft F/A-18 was replacing, required 30.9. [Ref. 20:p. 377]

The F/A-18 uses a wide range of fasteners. Fasteners are made from a broad range of materials. They range from ferrous and non-ferrous, to non-metallic (plastics). The Hornet's fasteners are primarily fabricated of aluminum alloy, titanium, stainless steel, and alloy steel. Appendix B illustrates the F/A-18's fasteners. There are some fastener design defects. However, there is no indication that they have experienced a counterfeit or substandard fastener problem. Direct contact with the Aviation Supply Office (ASO) indicated that no known quality problems exist with F/A-18 fasteners. [Ref. 21] ASO is responsible for supply support of Navy aircraft. They track all supply issues that impact Naval aircraft such as out of stock parts, parts inventories, and parts quality problems.

A. GOVERNMENT REQUIREMENTS IN FASTENER SELECTION

The Department of the Navy's acquisition process consists of four phases:

- Concept Exploration/Definition.
- Concept Demonstration and Validation.
- Full Scale Engineering Development.
- Production/Deployment.

The total project management process also considers the mission needs prior to the Concept Exploration/Definition phase and operations support, and weapons system retirement after the Production/Deployment phase. The mission needs, operations support, and system retirement components will not be discussed in this thesis. During the acquisition phases, certain events which can affect fastener selection must occur before entering into the next phase.

The intent of the Concept Exploration/Definition phase is to solicit and evaluate various concepts that will meet or exceed the mission needs. The Navy uses in-house Navy Research and Development laboratories, universities, and industry to develop and evaluate the different concepts. [Ref. 22:pp. 1-13] During this phase, there is no attempt to standardize or limit approaches that satisfy the requirements. The fastener selection would be irrelevant at this point but, if considered, would be based on the best solution possible and would not consider standardization or what is available in the market place. This phase produces concept documentation describing possible systems which satisfy the mission. It also highlights any deviations to the normal acquisition policy, such as competition feasibility, streamlining, and production risks. [Ref. 22:pp. 3-17]

The Concept Demonstration and Validation phase identifies the system concepts having the greatest potential for meeting the mission needs in a cost effective manner. During this phase, analyses, hardware fabrication, and test and evaluation will establish risks and uncertainties for at least one of the developed concepts. The objective is to reduce the risks to acceptable levels, and verify that the required technology is available to complete the project. [Ref. 22:p. 3-26] For fasteners, any special fastener requirements would be identified and solutions would have to be developed.

The Full Scale Engineering Development (FSED) phase produces the first prototype, a product baseline configuration design and a documentation package containing costs, schedule, logistic supportability, and performance constraints. The goal is to demonstrate and document a cost effective, reducible, operationally suitable, reliable, and maintainable production engineered system that meets the mission need. This is the first point at which a standardized flyable aircraft is constructed. It will be extensively tested to establish the hardware baseline, and to ensure that all of the functional and technical objectives can be achieved. The system attributes such as reliability, maintainability, safety and supportability, are established by the design. [Ref. 62:pp. 3-35--3-38] With consideration given to which fasteners are available, contract requirements and other special requirements which must be satisfied, the selection of fasteners is completed.

During the FSED phase, a technical evaluation of the prototype is accomplished. Based upon the results of the evaluation, there are several critical issues to be addressed. One of these issues is configuration management. The hardware baseline configuration is established. Any subsequent changes to the baseline vehicle must be considered carefully. Usually, the contractor no longer has the authority to change the baseline, as they did earlier in the development of the system. The program office now manages changes in the baseline. [Ref. 22:pp. 3-39--3-40] Fastener selection is complete and any changes must have a strong overriding justification.

The weapons system then moves into low rate initial production, which is part of the FSED. This provides an opportunity to ensure that construction can proceed in the production environment, based upon the data package available. Some other events occurring concurrently are validation of manuals and training, conducting advanced system testing and updating the production design. [Ref. 22:pp. 3-41--3-42]

The Production and Deployment phase is directed toward providing the desired operational capability and inventory levels. During this phase, configuration control is practiced rigorously. Changes are allowed only when justified by cost effectiveness or correction of problems or failures. [Ref. 22:p. 3-49] Changes in fastener selection would be rare now. From this point, the weapons system proceeds through the remainder of its life cycle.

B. F/A-18 FASTENER SELECTION PROCESS

McDonnell Douglas was contractually required to develop a standardization plan while designing the F/A-18 Hornet. A section of the plan addresses parts control and standardization. Parts control and standardization pertains to all electrical, electronic, mechanical, hydraulic and pneumatic parts, used in contractor-furnished airborne equipment, the airframe and Group Support Equipment (GSE) designed during aircraft development. "The objective is to maximize the use of derated high reliability parts and minimize the part types in AV-8B and F/A-18 designs." [Ref. 23:p. 2-1]

To reach selection of particular fasteners, the parts control and standardization program, an element of the standardization plan, coordinates and controls the selection, documentation, procurement and approval of parts. This begins during the Concept Demonstration and Validation phase and is completed during the Full Scale Engineering Development phase. [Ref. 23:p. 2-1]

Parts that need no approval by the Navy are those parts identified by government furnished baselines for the specific weapon system. These are called standard parts. The contractor has to track which standard parts have been selected. During design, a list of nonstandard and nonbaseline parts are compiled into a Program Parts Selection List (PPSL). This list is forwarded to the Navy for approval. Any parts that are not on the approved PPSL or not standard are nonstandard parts. The priority of parts selection is standard parts, parts from the PPSL, and nonstandard parts. All nonstandard parts must be approved by the Navy prior to use. [Ref. 23:p. 2-2]

All of the parts in the PPSL are controlled by either a Military Specification/Standard, a DoD/Naval Air Systems Command (NAVAIR) approved industry standard, or a standardized military drawing. All the Hornet's fasteners are listed in the PPSL.

A major sub-element of the parts control and standardization program is the Fastener Usage Policy (FUP). The FUP establishes the criteria for the selection and application of mechanical fasteners in the F/A-18 aircraft. The design intention is to provide structurally efficient connections which will be reliable and trouble free. [Ref. 23:p. 2-4]

McDonnell Douglas' FUP establishes criteria for the selection and application of mechanical fasteners in the F/A-18 aircraft. Specific elements called out in the Fastener Usage Policy are: selection criteria, usage limitations, hole call out information, and fastener strength allowances. It further divides fasteners into the major groupings of solid rivets, pin and collar fasteners, blind fasteners, bolts and nuts, and miscellaneous fasteners. [Ref. 24:p. vi]

To ensure that fasteners chosen are appropriate for the materials being jointed, the FUP has a table of preferred, acceptable and prohibited fastener materials. For example: two pieces of aluminum being joined will not have a copper fastener. This is prohibited by the FUP because copper can cause severe galvanic effects in aluminum. [Ref. 24:pp. VIII-X] Appendix C is the Fastener Material Table with the qualifiers explaining why some combinations are preferred, acceptable and prohibited. The intent is to reduce the incidence of fastener failure resulting from misapplication and design error.

The application of fasteners is considered specifically in the FUP. The policy contains an entire appendix devoted to the design allowances of fasteners. It considers the shear strength of each fastener on the F/A-18. There are charts indicating the maximum shear strength in relation to the fastener diameter and the thickness of the material.

They also provide guidance on acceptable or unacceptable use of the fastener listed. Appendix D is a representative example.

Appendix D of the FUP describes a step by step procedure for selecting fasteners. The procedure attempts to find the lowest common denominator, in terms of fasteners, to satisfy the requirements for joining structural doors and access panels. McDonnell Douglas has attempted to eliminate any questions or inconsistencies in fastener selection.

A representative example of fastener application is presented in Appendix E. [A1-F18AC-LMM-010, door 79] There are nine different acceptable fasteners, and 384 individual fasteners on this door. The selection process appears to have worked. Inspection of the usage data on part numbers HT4025L6-16, and NAS664VSHT, at NAS Lemoore's supply department indicated low usage. The quarterly usage for the two parts was ten and eight respectively. Navy-wide procurement of HT4025L6-16 was 11,274 in 1986, with no subsequent purchases indicated. For NAS664VSHT, there were 7700 procured in 1987 with no subsequent purchases indicated. These numbers indicate amounts procured and don't indicate the number of applications the fasteners are employed in. [Ref. 13]

Maintenance personnel interviewed at NAS Lemoore indicated their biggest maintenance problem was corrosion causing fasteners to seize. [Ref. 13] The documentation procedures the Navy uses, in most cases, does not reflect the manhours consumed by removing and replacing fasteners. Accordingly, there is no evidence to support technicians' belief that large amounts of time is spent on fasteners. An Air Force study also came to this same conclusion; namely, that the real scope of the fastener maintenance problem is unknown. However, General Goodell of the Air Force Staff stated that 50% of the manhours spent on the F-15 aircraft were fixing fastener problems and up to 40% of rework activity is due to fastener problems. The Navy, which operates in the same or even a more demanding environment, most likely experiences the same conditions.

The standardization plan seeks to limit the number of parts on the aircraft, while still satisfying airframe engineering requirements. Appendix B, which was drawn from the FUP, is a diagram showing what basic types of fasteners McDonnell Douglas has determined are the minimum necessary to satisfy airframe requirements.

C. QUALITY ASSURANCE PRACTICES

The selection methods do not reflect the purchasing and quality assurance process. McDonnell Douglas endeavors to obtain high quality fasteners by purchasing to military specifications or industry standards. In the case of the F/A-18, the pertinent military and civilian documents are listed in Appendix F. They track the quality record of their sources and have a receiving inspection program.

Further, their "procurement people try to buy direct from manufacturers." [Ref. 26] In effect, they avoid distributors.

During initial development of the weapons system, McDonnell Douglas acquires their own fasteners. Throughout the Department of Defense, the Defense Logistics Agency (DLA) acts as a central manager for common use spare parts. DLA purchases and forwards requisitioned fasteners to all of the services. As an aircraft enters the fleet, ASO assumes responsibility within the Navy for supplying replacement fasteners. They accomplish this by tracking DLA and Navy Supply Center inventory levels. ASO assumes the fasteners received from DLA meet the specified requirements. ASO has indicated that no quality problems have been experienced with any F/A-18 fasteners. [Ref. 21]

The Aviation Supply Office and DLA work together to ensure DLA contracts for Navy requirements. The Aviation Supply Office provides a list of required fasteners for new weapons systems to DLA, which is used to ensure that they stock the correct items. The list contains possible vendors. They generate their list for DLA based on a list of fasteners used on the aircraft which is prepared by McDonnell Douglas. The contractor also provides a list of possible vendors. [Ref. 21]

As stated, there are no known problems with quality on Hornet fasteners. However, one of McDonnell Douglas' fastener suppliers, Voi-Shan, has been suspended from doing business with the government. Voi-Shan is under suspicion for "routinely falsified manufacturing reports and test results from January 1980 through February (1989)." [Ref. 27] Under the suspension, government contractors and subcontractors cannot purchase from Voi-Shan. It is McDonnell Douglas' policy not to buy from a suspended company for any contract, not just government contracts. [Ref. 26] Voi-Shan has supplied the type fasteners used on the F/A-18. However, there is no indication that those fasteners were substandard or counterfeit. [Refs. 21,25]

D. FASTENER USAGE

Fasteners used on the F/A-18 were chosen according to the FUP. As stated earlier, selection criteria, usage limitations, hole call out information, and fastener strength allowances indicate the type of fastener used. Panels that are commonly opened tend to have bolts or quick release fasteners. While some of these fasteners have failed, there has been no indication of procurement quality problems. The primary reason for fastener failures on the F/A-18 have been corrosion, over-stressed loads, and the finish on titanium fasteners. Corrosion is the single most common cause of fastener failure. Even these failures appear rare, based on the usage data of F/A-18 fasteners, provided by NAS Lemoore's supply department.

One of the biggest problems with identifying fastener deficiencies is that no failure data are collected. Fastener replacement and repairs are included in other systems maintenance actions. In an Air Force study, fasteners were the second largest problem for line personnel, with tools considered the only area that was worse. [Ref. 28:p. 20b] Fasteners account for more than 40% of the structural failures on Air Force aircraft. [Ref. 65]

The Navy has the same deficiency in tracking fastener failures. Minor maintenance such as tightening screws on panels during post-flight checks are not documented. Fastener tightening is documented as a post-flight check, which includes other items not related to fasteners.

E. SUMMARY

This chapter has examined the government's approach to fastener selection and standardization. The Department of Defense acquisition process was studied, highlighting the points where fastener selection was critical and who controlled final fastener selection in the development process of new weapons systems.

McDonnell Douglas' F/A-18 fastener usage policy was examined as it relates to the Department of Defense acquisition process. It went on to show how DLA gets their list of fasteners and possible vendors.

Both McDonnell Douglas' and DLA's quality assurance practices were reviewed. This examination was based upon the practices that were in place during the development and early deployment of the F/A-18. Also highlighted was the failure of the process for both the contractor and DLA, in selection of reputable vendors. Despite DLA's quality assurance practices in obtaining fasteners, the Hornet has no known fastener procurement quality deficiencies.

The final element of this chapter was a brief description of the problem in identifying aircraft fastener failures. The two most significant points are: the volume of failures, and the inability of the Air Force and the Navy to track those types of failures.

VI. ANALYSES AND RECOMMENDATIONS

The purpose of this thesis was to examine the counterfeit fastener issue as it relates to the Department of Defense (DoD). Specific areas of attention have been given to standards in general, fastener standards, and the methods in which the standards are applied. The source of information for this paper has been developed from site visits, personal interviews, and a review of the literature on the topic.

Chapter I gave a brief presentation of the role of standards and fasteners in the economy today. It was followed by an overview of the counterfeit fastener problem in Chapter II. A complete description of the primary fasteners being considered was included. Chapter III was a primer on standards and specifications. A description of the fastener problem at the Defense Industrial Supply Center (DISC), which is the focal point of this issue for DoD, was presented in Chapter IV. In Chapter V the F/A-18 Hornet was used to illustrate how the fastener selection and procurement process works.

A. FASTENER STANDARDS

Chapter III provides a complete explanation of how standards are generated, why they are so widely accepted, and why they are so necessary. Voluntary standards are the cornerstone of our economic system. They are a public good, available to all such that no single person can be denied their use. Standards must be recognized and consistently applied in the economic system in order to perform their service. When this does not occur, the exchange system begins to break down. Therefore, it is critical that standards are developed and enforced to further economic activity and development.

The key issue remains: most standards in use today are voluntary and our economic system is dependent upon these standards. The fact that standards are primarily voluntary places the burden of enforcement upon the person or organization requesting a certain standard. The organizations which draft the standards realize this, as indicated by the requirement for enforcement being placed upon the consumers in the standards documents.

Fastener standards are similar to most voluntary standards. Fastener standards must also be consistently applied and conformed with. Recently, standard compliance has been misrepresented by unethical manufacturers and distributors. They have knowingly represented grade 8.2 or less fasteners as grade 8. This shows the standards and economic system breaking down within the fastener industry.

Traditionally, blame would be placed on the unethical businessmen who compromised the standards. However, the burden of enforcement is on the end user. A breakdown in the standards system would then be the responsibility of both the supplier an the consumer. The supplier would be responsible for not complying with the voluntary standard, as is accepted practice. The consumer would be responsible for not ensuring compliance.

The government is considering intervening in voluntary standards compliance. House Resolution (HR) 3000 is the most recent proposal. The intent is to provide a public good, in that all members of society would be protected from counterfeit fasteners. This would impose a cost which would be reflected in the purchase price of fasteners. However, no one manufacturer or consumer would be saddled with this expense. The value of a protected public and government could outweigh the cost.

There is a problem with HR 3000 as it is currently written. The general purpose and approach is correct. However, the proposed law is drafted in such a way as to provide a means of avoiding the requirements by the use of the small lot exception. The exception would encourage manufacturers and distributors to sell in small lots of 50 items or less. The economic advantage would soon be lost as all sales would be in lots of 50 or less. No public good would be created and the public would remain at risk from counterfeit and/or substandard fasteners.

B. COUNTERFEIT FASTENERS WITHIN THE DEPARTMENT OF DEFENSE

The Defense Industrial Supply Center is the focus of this issue within the DoD. It is the primary source of fasteners for the military services and one of the largest single purchasers of fasteners in the United States. Its actions not only impact the government, but the civilian market as well.

The Defense Industrial Supply Center, as required by the Federal Acquisition Regulations (FAR), competed the contracts for fasteners. The intent was to procure fasteners at the lowest possible cost. This approach has merit. However, their method for ensuring compliance was questionable at best. DISC relied on Certificates Of Compliance, which placed their quality totally at the discretion of their suppliers. The result appears to have been the introduction of counterfeit and substandard fasteners into DoD's inventories.

There were contributing factors that aggravated DISC's problem. They would not have had any impact if DISC had taken responsibility for quality. Within DISC's organization, their personnel conceded that standard enforcement had become lax. The primary reason for this was a lack of resources. As a result of not enforcing the standards used to procure fasteners, DISC allowed this problem to occur within the Department of Defense.

C. THE F/A-18 FASTENER SELECTION AND PROCUREMENT PROCESS

The Navy has very specific procedures for the development and procurement of new weapons systems. McDonnell Douglas was contractually required to follow these procedures. They did this in a methodical and effective manner. The result has been high quality application of the correct standard and fastener to the requirement. The actual selection process appears to be very effective.

Early in the F/A-18 development process McDonnell purchased fasteners outside of the defense department. Their process again appears to be effective. Key elements include: avoiding distributors and purchasing from the manufacturer whenever possible, a receiving inspection program, and tracking the quality record of their sources. These steps appear to have protected McDonnell Douglas from counterfeit fasteners.

McDonnell Douglas was not able to avoid the unethical businesses. Voi-Shan, currently a suspected supplier of counterfeit fasteners, was one of their suppliers. The procurement procedures followed by McDonnell Douglas successfully prevented Voi-Shan from attempting to pass on counterfeit fasteners to the company.

D. CONCLUSIONS AND RECOMMENDATIONS

The problems experienced by DISC could have been avoided. The experiences of the F/A-18 indicate that a strong acceptance inspection program will deter suppliers from providing a substandard product. Although the exact type of fasteners that impacted DISC's inventories are different than those used on the F/A-18, the concepts are the same. Further, the grade of fasteners that the F/A-18 utilizes have a quality problem of their own which DISC is resolving. However, the F/A-18 continues to have no quality problems with their fasteners. This would seem to validate the inspection program.

The issue of compromising standards can impact any product. The lessons learned from the grade 8 fasteners have been hard, yet they could be applied to almost any product which the government purchases.

The Department of Defense is in a better position to inspect and protect their interests than are most small businesses. Government intervention in the standard setting process can have a far-reaching effect. The small business-man may need the government's help in protecting himself and his customers. The externality of the government intervening in the standards setting process may be a better protected government, resulting in a better protected populace.

The opposite perspective might be that government intervention in standards is the first step in the government becoming involved in more and more aspects of the public's daily routine. This could be placed under the guise of a "public good." Thus, the externality of government intervention may not always be considered positive.

There are three basic recommendations derived from the research on this thesis. The first is for DoD to inspect incoming products according to the pertinent specifications and the customary commercial practices. This approach has consistently been the most effective means of ensuring standard compliance.

The second recommendation is for the Department of Defense to examine other means of contracting in a competitive market. Selecting a supplier based solely upon the least cost, as indicated in this thesis, will not always satisfy the requirements. The Food Machines Corporation (FMC) has developed a process that rewards quality suppliers. Their system takes a number of factors into consideration, such as quality and delivery performance. Suppliers are graded on those factors, and follow-on source selection considers those grades. There are other companies that have similar systems. DoD would be well advised to examine a number of them and develop the one that would ideally suit their needs.

The final recommendation is that DoD support HR 3000. If this bill becomes law, DoD will have real recourse for substandard suppliers. The quality and inspection costs in administering fastener contracts can also be reduced. HR 3000 will also help protect the small businessman and the general public. This recommendation is qualified in that the small lot exception of the bill should be eliminated, prior to DoD support. The benefits would be negated if the exception remained.

APPENDIX A

EXCERPT FROM SAE J429 STANDARDS

This is an excerpt from the SAE Standard J429. It shows the grade designations, the mechanical requirements, and identification markings for bolts, screws, studs, SEMS, and U-bolts.

MECHANICAL REQUIREMENTS AND IDENTIFICATION MARKING FOR BOLTS, SCREWS, STUDS, SEMS, AND U-BOLTS[i]

Grade Designation	Products	Nominal Size Dia, In	Full Size Bolts, Screws, Studs, Sems		Machine Test Specimens of Bolts, Screws, and Studs				Surface Hardness	Core Hardness		Grade Identification Marking[j]
			Proof Load (Stress), psi	Tensile Strength (Stress) Min, psi	Yield[a] Strength (Stress) Min, psi	Tensile Strength (Stress) Min, psi	Elongation[f] Min, %	Reduction of Area Min, %	Rockwell 30N Max	Rockwell Min	Rockwell Max	
1	Bolts, Screws, Studs	1/4 thru 1-1/2	33,000	60,000	36,000[b]	60,000	18	35	—	B70	B100	None
2	Bolts, Screws, Studs	1/4 thru 3/4[c]	55,000	74,000	57,000	74,000	18	35	—	B80	B100	
		Over 3/4 to 1-1/2	33,000	60,000	36,000[b]	60,000	18	35	—	B70	B100	None
4	Studs	1/4 thru 1-1/2	—	115,000	100,000	115,000	10	35	—	C22	C32	None
5	Bolts, Screws, Studs	1/4 thru 1	85,000	120,000	92,000	120,000	14	35	54	C25	C34	
		Over 1 to 1-1/2	74,000	105,000	81,000	105,000	14	35	50	C19	C30	
5.1[d]	Sems[h]	No. 6 thru 3/8 Sems only, thru 5/8	85,000	120,000	—	—	—	—	59.5[g]	C25	C40[g]	
5.2	Bolts Screws	1/4 thru 1	85,000	120,000	92,000	120,000	14	35	56	C26	C36	
7[e]	Bolts Screws	1/4 thru 1-1/2	105,000	133,000	115,000	133,000	12	35	54	C28	C34	
8	Bolts, Screws, Studs	1/4 thru 1-1/2	120,000	150,000	130,000	150,000	12	35	58.6	C33	C39	
8.1	Studs	1/4 thru 1-1/2	120,000	150,000	130,000	150,000	10	35	—	C32	C38	None
8.2	Bolts Screws	1/4 thru 1	120,000	150,000	130,000	150,000	10	35	61	C35	C42	

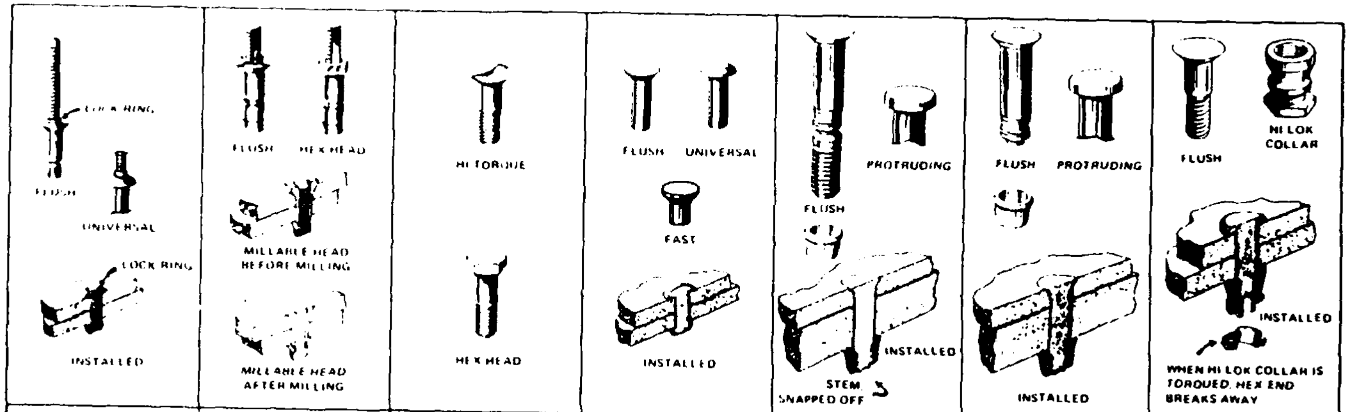
[a] Yield strength is stress at which a permanent set of 0.2% of gage length occurs.
[b] Yield point shall apply instead of yield strength at 0.2% offset.
[c] Grade 2 requirements for sizes 1/4 through 3/4 in apply only to bolts and screws 6 in and shorter in length, and to studs of all lengths. For bolts and screws longer than 6 in, Grade 1 requirements shall apply.
[d] Grade 5 material heat treated before assembly with a hardened washer is an acceptable substitute.
[e] Grade 7 bolts and screws are roll threaded after heat treatment.
[f] See Table 6 for gage length.
[g] Hex washer head and hex flange products without assembled washers shall have a core hardness not exceeding Rockwell C38 and a surface hardness not exceeding Rockwell 30N 57.5.
[h] Sems and similar products without washers.
[i] See footnote 2 of text.
[j] Not applicable to studs or slotted and cross recess head products.

APPENDIX B

F/A-18 FASTENERS DIAGRAM

Appendix B illustrates the fastener types used on the F/A-18. This table includes head types, fastener materials, and the advantages and disadvantages. The source is McDonnell Aircraft Company's fastener usage policy.

F-18 FASTENERS



	BLIND RIVET	JO BOLTS	BOLTS	SOLID RIVETS	HUCK LOCKBOLTS	HUCK STUMPS	HI LOKS
HEAD TYPES	TENSION	TENSION SHEAR	TENSION SHEAR	SHEAR FAST	TENSION SHEAR	SHEAR	TENSION SHEAR
FASTENER MATERIALS	ALUMINUM ALLOY A286 STAINLESS STEEL	ALUMINUM ALLOY TITANIUM A286 STAINLESS STEEL	ALLOY STEEL TITANIUM PH 13 8 MO STAINLESS STEEL	ALUMINUM ALLOYS TITANIUM	PH 13 8 MO STAINLESS STEEL TITANIUM	TITANIUM PH 13 8 MO STAINLESS STEEL	TITANIUM PH 13 8 MO STAINLESS STEEL
NUT OR COLLAR MATERIALS			ALLOY STEEL A286 STAINLESS STEEL	—	ALUMINUM ALLOY MONEL	ALUMINUM ALLOY MONEL	HI LOK COLLARS ALUMINUM ALLOY, A286 STAINLESS STEEL
ADVANTAGES AND DISADVANTAGES	FOR BLIND APPLICATIONS INSTALLED FROM HEAD SIDE. STEM MECHANICALLY LOCKED BY SWAGED LOCK RING. HAND INSTALLATION TOOLS PERMIT USE IN LIMITED ACCESS AREAS NOT FOR PRIMARY TENSION APPLICATIONS	WIDE VARIETY OF INSTALLATION TOOLS PERMIT USE IN LIMITED ACCESS AREAS. HEADS OF FLUSH ALUMINUM JO BOLTS ARE SHAVED FLUSH AFTER INSTALLATION	GOOD HEAD STRENGTH REUSABLE	HOLE FILLING. NO CLAMP UP. LARGER DIAMETERS IN HIGH STRENGTH MATERIALS MUST BE SQUEEZED. NOT FOR PRIMARY TENSION APPLICATIONS	POSITIVE CLAMP UP COLLAR SEATED BY GUN PULLING ON STEM. CAN BE PULLED INTO INTERFERENCE FIT HOLES IN ALUMINUM BY GUN. PULL GUNS ARE RELATIVELY HEAVY AND BULKY REQUIRING GOOD ACCESS TO COLLAR SIDE. INSTALLED BY ONE MAN	SOME CLAMP UP. LOW DRIVING FORCE	CONTROLLED CLAMP UP WRENCHED FROM NUT SIDE ONLY. NO RECESS OR WRENCH FLATS ON HEAD

APPENDIX C

F/A-18 FASTENER MATERIAL TABLE

This appendix indicates what type materials may be joined with certain type fastener materials. It provides preferred, acceptable and prohibited applications. Justifications are provided in the notes. The source is McDonnell Aircraft Company's fastener usage policy.

STRUCTURAL ALLOYS BEING JOINED	FASTENER MATERIAL		
	PREFERRED	ACCEPTABLE	PROHIBITED
Aluminum to Aluminum	Aluminum (Anodized) Aluminum Coated Steel, 1	Cadmium Plated Steel 7 Titanium 5 PH13-8Mo 5 A-286 5	Monel, Copper, Brass 2 Inconel
Titanium to Titanium, Austenitic Stainless Steel, or Nickel Base Alloys	Titanium, A-286 PH13-8Mo		Cadmium Plated Steel Fasteners, 3 Aluminum, or 4 Aluminum Coated 3 Fasteners
Titanium to Aluminum	Titanium 5	PH13-8Mo 5 Aluminum 4 Alloy Steel Aluminum Coated 1 4	Monel 2 Cd Plated Fasteners 3
Graphite Composite	Titanium	PH13-8Mo 8 6 A-286 8 6	Monel 6 Cd Plated Steel 6 Aluminum or Aluminum Coated Fasteners 6

1. Aluminum coating system per MCAIR P.S. 13143.

2. These alloys can cause severe galvanic effects in aluminum.

3. Cadmium or aluminum coat will galvanically corrode in a short time when in contact with titanium. This then leaves the steel fastener unprotected. In addition, there is evidence that cadmium in contact with titanium can cause microcracks in the titanium after a short period of only moderately elevated temperature and sustained tension stress.

4. Small amounts of aluminum (fastener) or aluminum coat will galvanically corrode in a short time when surrounded by large amounts of titanium (joined material). Aluminum fasteners or aluminum coated fasteners are acceptable for joining aluminum to titanium only if the fastener is wet installed per MCAIR PS 13607 or PS 11344 as applicable in a well drained area.

5. Bare titanium, A-286, and PH13-8Mo fasteners are suitable in contact with aluminum or aluminum/titanium combination structure, only if wet installed per MCAIR PS 13607 or PS 11344 as applicable. These materials are compatible with titanium structure without a barrier.

6 Graphite combined with any fastener material other than titanium will result in corrosion of the fastener.

7 Cadmium plated steel fasteners in aluminum on exterior locations shall be avoided. REASON: Rusting occurs in approx. 12 months or less and produces galvanically promoted corrosion of the aluminum. Acceptable for use on internal structure.

8 Use of these fastener materials are acceptable contingent upon:

- o permanency,
- o wet installation with sealant per MCAIR PS 13607 or PS 11344 as applicable.
- o overspray of fastener patterns with sealant.

Do not use except when availability dictates or cost significant. Titanium preferred.

D. Care is required to assure that no loose fasteners or fastener elements can be drawn into engine inlets to cause foreign object damage to engines. Engine inlet duct skins should not contain blind fasteners or threaded fasteners secured only by self-locking nuts. When threaded fasteners are required in this area they should be safetyed with cotter pins or lockwire. This restriction includes those pin and collar fastener types in which the "collar" is essentially a locknut. C

E. The upper sheet of a shear joint, when countersunk to receive a flush fastener head, shall always be thick enough to contain the entire countersink without a sharp edge at the bottom. The knife edge of sheet represents a significant stress riser. In addition, there is a tendency for the flush head to tilt and ride up the slope of the countersink resulting in a low joint yield strength and reduced fastener fatigue life. The ratio (maximum countersink depth divided by minimum sheet thickness) shall be no more than 0.7 for fatigue critical structure and no more than 0.8 for any other structural applications.

F. Interference fit fasteners or fasteners that feature shank expansion during installation must not be used in composites or in metal applications that would impart sever peripheral tension stress in materials subject to stress corrosion cracking (see Note "M" - General Critiera).

G. Some fastener types such as solid rivets and stump lockbolts require high forces for installation which can, in some cases, damage rigid structure such as castings, machined flanges, and composite structure. Every effort should be made to avoid fastener installations in which there is potential for structural damage. Problem areas include: C

Severe Loads: Vibration driving of titanium solid rivets.

<u>Moderate Loads</u>: Vibration driving of aluminum solid rivets or stump lockbolts.

<u>No Problem</u>: Fasteners that are squeeze driven or are installed by rotating a threaded nut or collar.

H. Dimpling is more expensive than countersinking, and should be avoided.

I. Fasteners of titanium and aluminum have low enough magnetic permeability to be suitable for nonmagnetic applications. Low alloy steel and PH13-8Mo material fasteners must be avoided in such applications.

J. Final size fastener holes may be punched (rather than drilled or reamed) only when specifically permitted by Engineering drawing. Because tool marks in the thickness direction can be severe stress risers, hole punching (by Drawing Note) shall be allowed only in non-structure parts, such as 6M62 cut-outs in shims and spacers.

K. Attempts should be made to avoid locating fasteners directly opposite each other in the legs of angles of 90° or less unless there is adequate access space.

L. Lockwashers shall not be used since they damage the finish system setting up corrosion paths.

M. Restrictions on interference fit and expanding shank fasteners in materials with high to moderate stress corrosion cracking resistance are as follows:

APPENDIX D

F/A-18 FASTENER ALLOWANCES TABLE

Appendix D illustrates the fastener allowances in terms of strengths and applications. The source is McDonnell Aircraft Company's fastener usage policy.

F-18 FASTENER ALLOWABLES

Effective Ultimate Allowable Strengths for Close Fit
Steel Bolts Countersunk in Aluminum Sheet - lbs per Bolt

Fasteners	HI-LOKS - ST3M760V BOLTS - NAS 663VH - 668VH 95 KSI SHEAR TITANIUM FASTENERS					
Bolt Size	#10	1/4	5/16	3/8	7/16	1/2
Single Shear Strength	2,690	4,650	7,300	10,500	14,300	18,650
Sheet Material	Bare and Clad 7075-T6					
Hole Size	0.1900 +0.0012 -0.0005	0.2495 +0.0017 -0.0000	0.3120 +0.0017 -0.0000	0.3745 +0.0017 -0.0000	0.4370 +0.0017 -0.0000	0.4995 +0.0017 -0.0000
0.063	1,284	. . .	. . .	. . .	. . .	. . .
0.071	1,404	1,938	. . .	. . .	. . .	. .
0.080	1,548	2,205	2,680	. . .	. .	. . .
0.090	1,695	2,415	3,070	3,565	4,475	. . .
0.100	1,848	2,607	3,438	4,060	4,910	5,100
0.125	2,235	3,096	4,038	5,121	6,000	6,791
0.160	2,690	3,825	4,944	6,165	7,400	8,812
0.190	. . .	4,425	5,700	7,080	8,560	10,202
0.250	. .	4,650	7,215	8,880	10,760	12,450
0.312	. .	. .	7,300	10,500	12,980	15,000
0.375	. . .	. . .	. . .	. .	14,300	17,512
0.500	.	. . .	. . .	. . .	. .	18,650

Notes:

1. **All strengths are for 2D or greater edge distance.**
2. **Reference MCAIR 339, Page 1.36.**
3. Refer to Figure C-11.1 for interpolation curves.

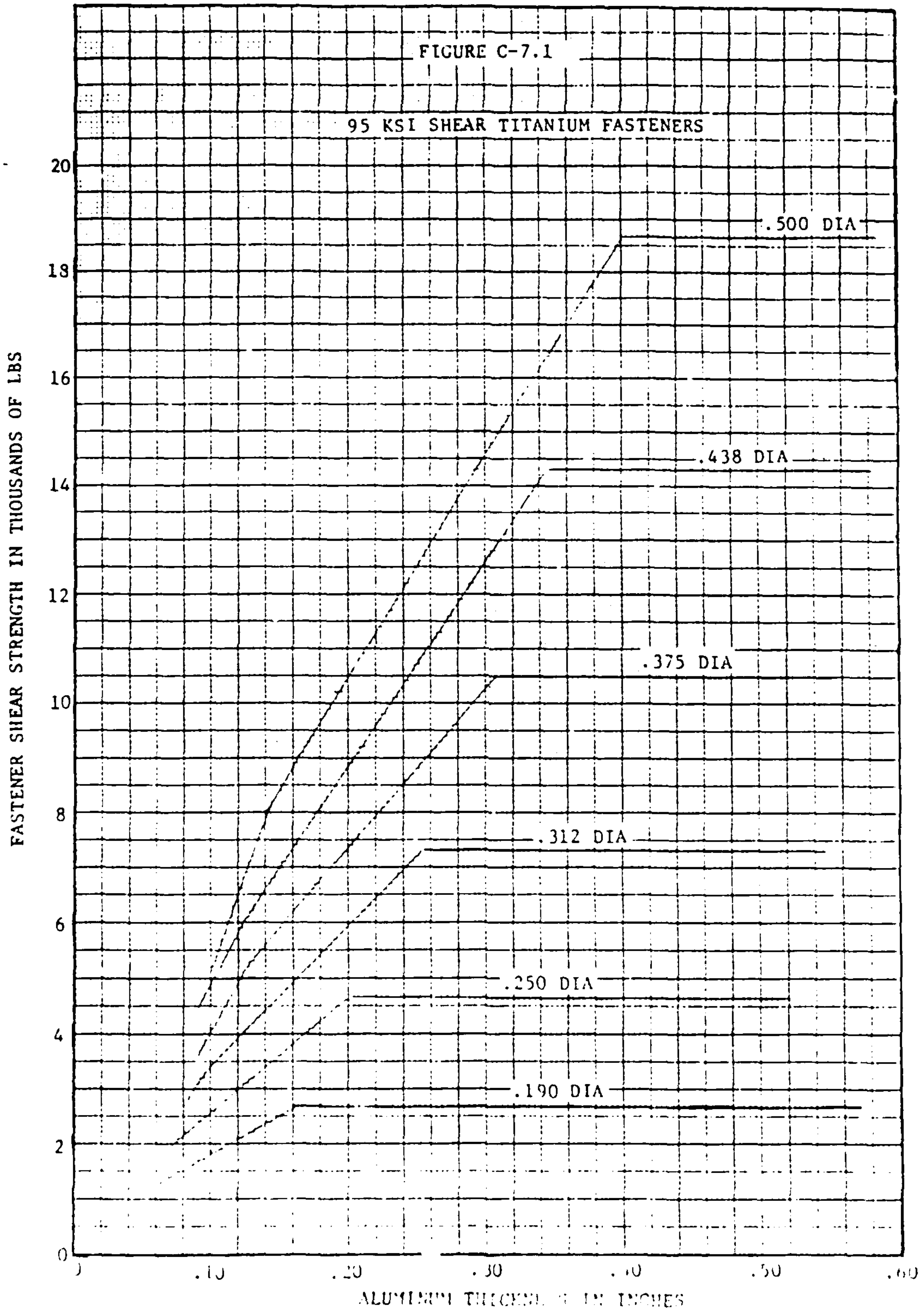


FIGURE C-7.1
95 KSI SHEAR TITANIUM FASTENERS
.500 DIA
.438 DIA
.375 DIA
.312 DIA
.250 DIA
.190 DIA
FASTENER SHEAR STRENGTH IN THOUSANDS OF LBS
0
2
4
6
8
10
12
14
16
18
20
0
.10
.20
.30
.40
.50
.60

APPENDIX E

F/A-18 FASTENER APPLICATION EXAMPLE

Appendix E is an excerpt from the F/A-18 maintenance manual. It is an example of a common application of fasteners on the F/A-18. The illustration highlights the volume of fasteners used even in common applications.

IDX NO.	NOMENCLATURE	PART NUMBER	QTY	TORQUE IN-LBS
1	Screw 2	HT4025L6-16	7	85-125
2	Screw 1 Screw 3	NAS665V18HT NAS665V20HT	83 83	65-95 65-95
3	Screw	NAS664V16HT	22	40-60
4	Screw	NAS664V8HT	127	40-60
5	Screw	NAS665V9HT	60	65-95
6	Screw 2	HT4025L6-16	1	85-125
7	Screw	NAS665V20HT	54	65-95
8	Screw	NAS665V9HT	46	65-95
9	Screw	NAS664V8HT	67	40-60

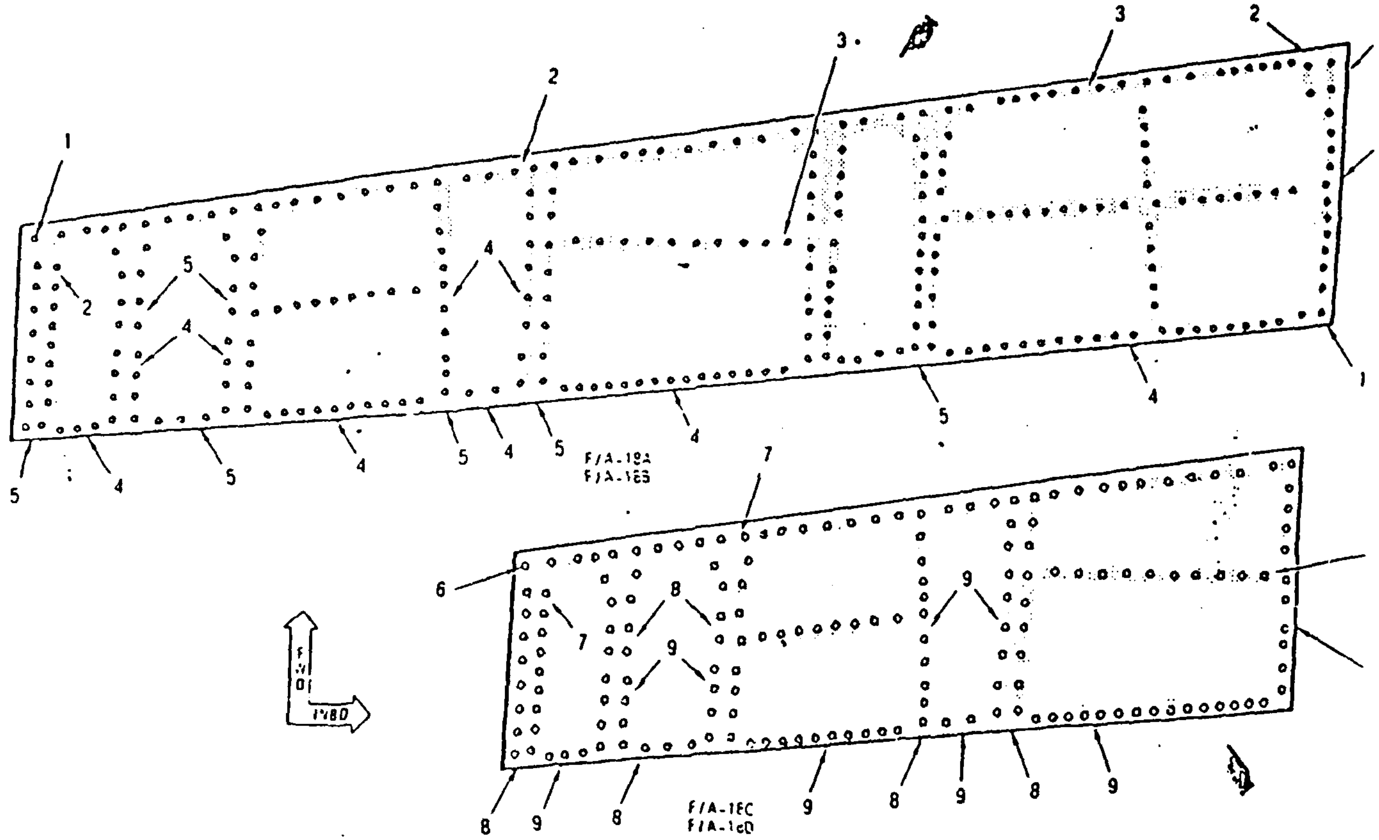
LEGEND

1 161353 THRU 161528.

2 Install fasteners wet with MIL-S-83430 sealing compound. For preparation and application (A1-F18AC-SRM-200, WP011 00).

3 F/A-18A, F/A-18B 161702 AND UP.

Door 79 Removal and Installation (Sheet 2)



Door 79 Removal and Installation
(Sheet 1)

APPENDIX F

F/A-18 PREFERRED FASTENER LISTING

Appendix F is a list of standards used for preferred fasteners on the F/A-18. The list is an excerpt from McDonnell Aircraft Company's fastener usage policy. When one of the standards is selected for use, no further approval is required to incorporate the fastener on the aircraft.

F-18 PREFERRED FASTENERS

This appendix provides a list of those fasteners and fastener elements discussed in this report. They are arranged numerically by part number:

MILITARY STANDARDS	INDUSTRY STANDARDS	MCDONNELL STANDARDS	
AN960	NAS514	3M62	ST3M683
M83454	NAS600	3M117	ST3M718
MS14108	thru	3M193	ST3M719
MS20002	NAS606	3M220	ST3M720
MS20426	NAS653	3M302	ST3M721
MS20470	thru	3M303	ST3M723/724
MS21042L	NAS658	3M304	ST3M730
MS21059L	NAS663	3M305	ST3M740
MS21060L	thru	3M310	ST3M741
MS21061L	NAS668	3M384	ST3M742
MS21062L	NAS673	3M385	ST3M743
MS21209	thru	3M394	ST3M747
MS21244	NAS678	3M891	ST3M748
MS21297	NAS1080	4M30	ST3M752
MS24693	NAS1291	9M184	ST3M753
MS51957	NAS1398	9M185	ST3M757
MS122116	NAS1399	ST3M404	ST3M758
thru	NAS1587	ST3M430	ST3M759
MS124829	NAS1671	ST3M442	ST3M760 C
	NAS1672	ST3M443	ST3M761
	NAS1673	ST3M448	ST3M762
	NAS1674	ST3M454	ST3M764
	NAS1801	ST3M455	ST3M781
	NAS1802	ST3M463/465	ST3M782
	NAS2605	ST3M470	ST3M783
	thru	ST3M509	ST3M790
	NAS2612	ST3M512	ST3M791
	NAS2705	ST3M523	ST3M793
	thru	ST3M525	ST3M797
	NAS2712	ST3M541	ST3M806
		ST3M542	ST3M816
		ST3M543/545	ST3M828
		ST3M573	ST3M829
		ST3M608	ST3M832
		ST3M652	ST3M852
		ST3M675	ST3M861
		ST3M676	ST3M873

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